Challenges for in situ cal/val from space-time variability

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A key SWOT requirement

2.7.2.a [Requirement] The sea surface height error spectrum (cross-track average of the along-track spectra computed at different cross-track locations over the swath) in the wavelength range smaller than 1,000 km shall not exceed the spectrum envelope given in Figure 1 and the formulas below. This requirement holds for significant waveheights (SWH) less than 2 meters.
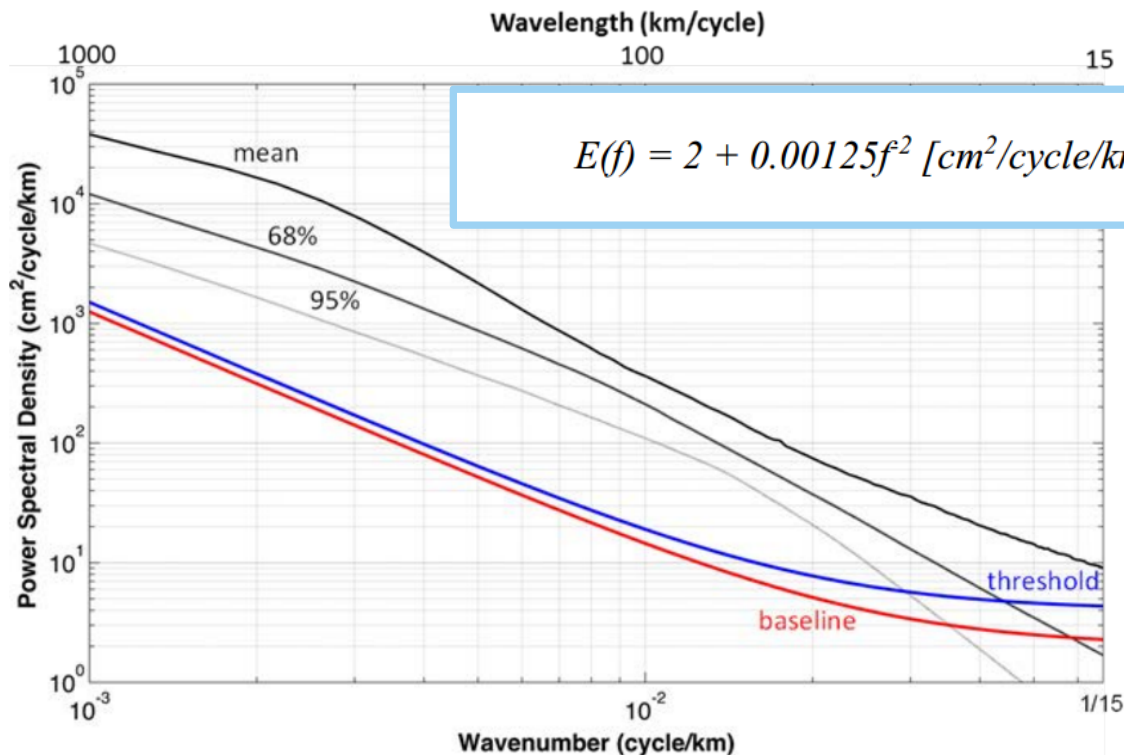
$$E(f) = 2 + 0.00125f^2 \ [cm^2/cycle/km] \quad 15 \ km < \lambda < 1,000 \ km \quad (2)$$

From SWOT Science Requirements Document

Need for synoptic sampling

The cal/val team has discussed need to examine the difference of the SWOT data from the validation data

$$h = \text{SSH} + n$$

Measurement is real variability plus noise

Difference of spectra

$$\left\langle h_1^2 \right\rangle - \left\langle h_2^2 \right\rangle = \left\langle n_1^2 \right\rangle - \left\langle n_2^2 \right\rangle$$

Underestimates noise

Spectrum of difference

$$\left\langle \left(h_1 - h_2 \right)^2 \right\rangle = \left\langle n_1^2 \right\rangle + \left\langle n_2^2 \right\rangle$$

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If the measurements are not collected at the same place and time, we risk interpreting real variability as measurement noise

$$\left\langle (h_1 - h_2)^2 \right\rangle = \left\langle (\text{SSH}_1 - \text{SSH}_2)^2 \right\rangle + \left\langle n_1^2 \right\rangle + \left\langle n_2^2 \right\rangle$$

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If the measurements are not collected at the same place and time, we risk interpreting real variability as measurement noise

If the validation measurements are not collected synoptically (all at one time), we risk interpreting temporal variability as spatial variability.

(There is a separate issue that arises from measuring proxies for SSH)

Horizontal wavenumber-frequency spectrum of SSH

(a) HYCOM SSH spectrum

(b) MITgcm SSH spectrum

Units are $\log_{10}$ [cm^2 /(cpd)/(cpkm)]
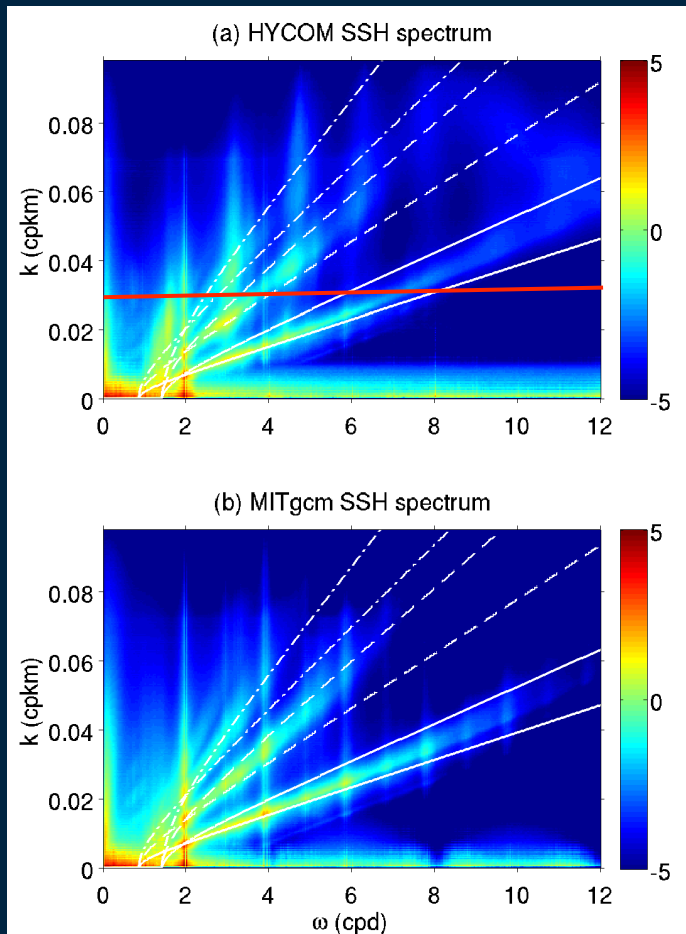
(Savage et al. in preparation))

~30 km wavelength

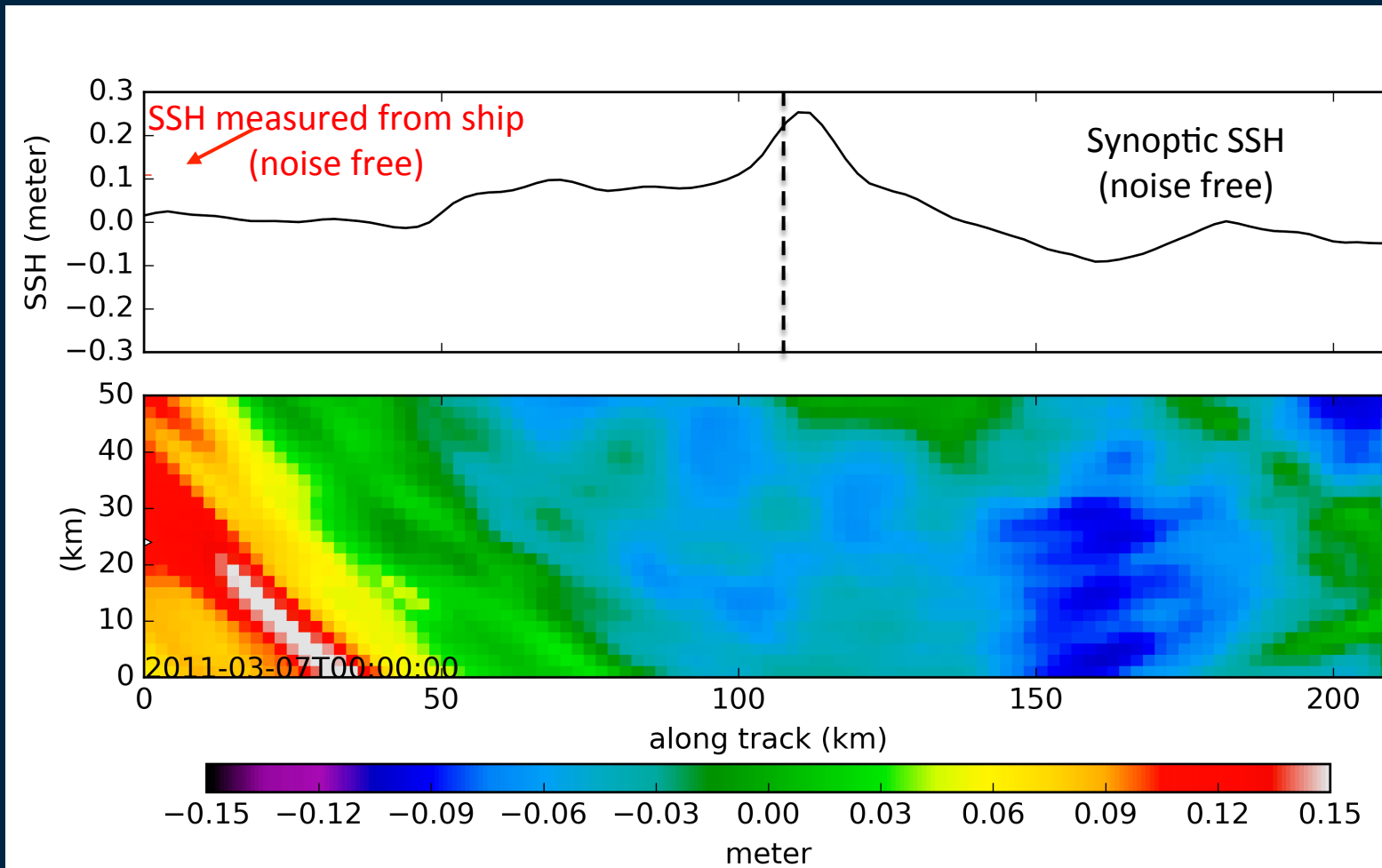A significant fraction of the 20-100 km SSH variability fluctuates on timescales of 3-12 hours

If the validation data are not sampled synoptically (at the same time and place as SWOT), we will misinterpret some of this variability as measurement errors

Sampling errors can swamp measurement noise

Ship moving 5 m/s (~10 knots) over 12 hours

Conclusions

☐ SWOT along-track sampling will be effectively synoptic. The along-track wavenumber spectrum needs to be validated.

☐ The high-frequency variability of the SSH field at small spatial scales (20-100km) will make it difficult to use some conventional in situ measurement approaches for cal/val– we will need some spatial arrays of instruments for synoptic sampling
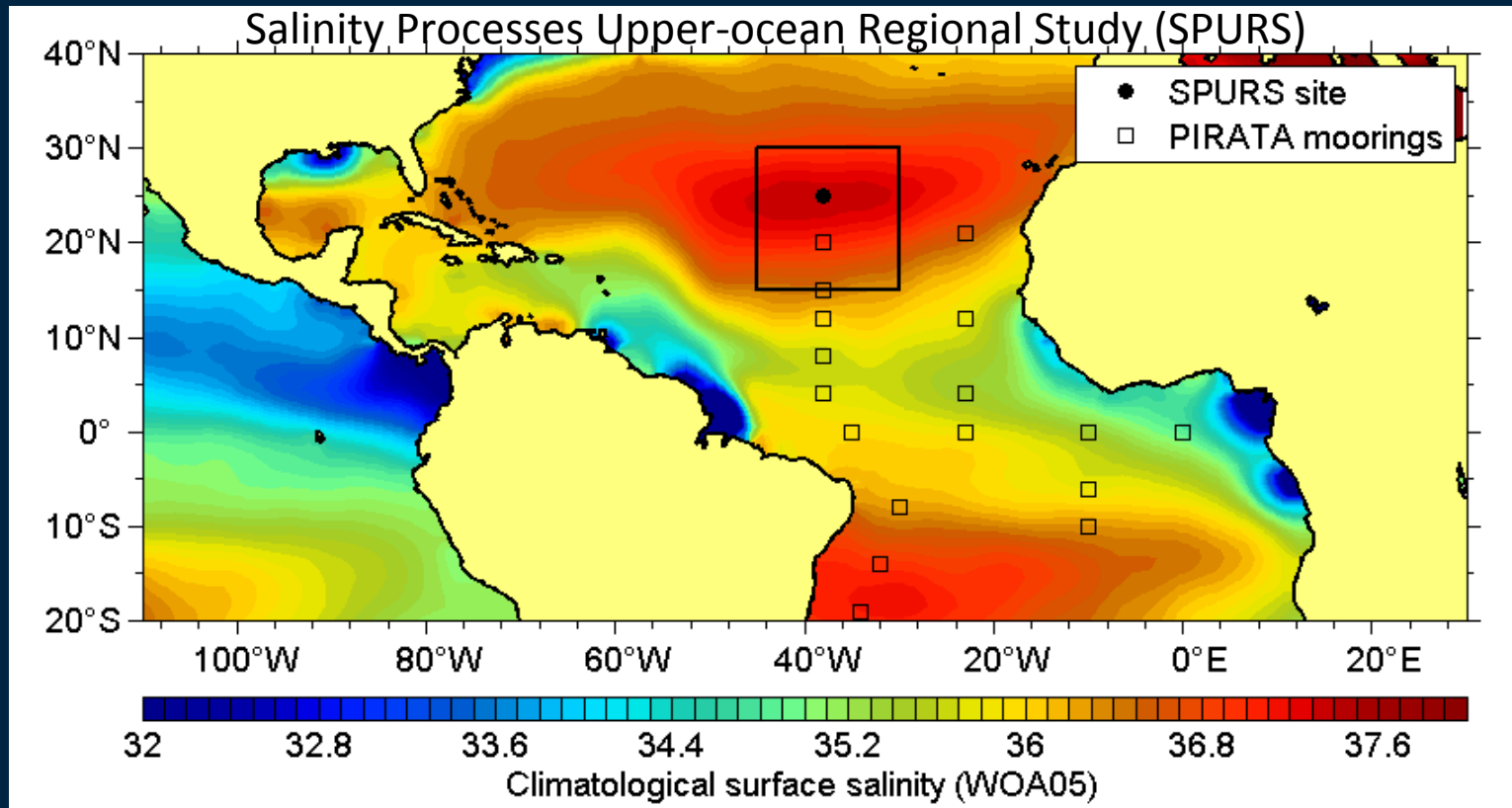
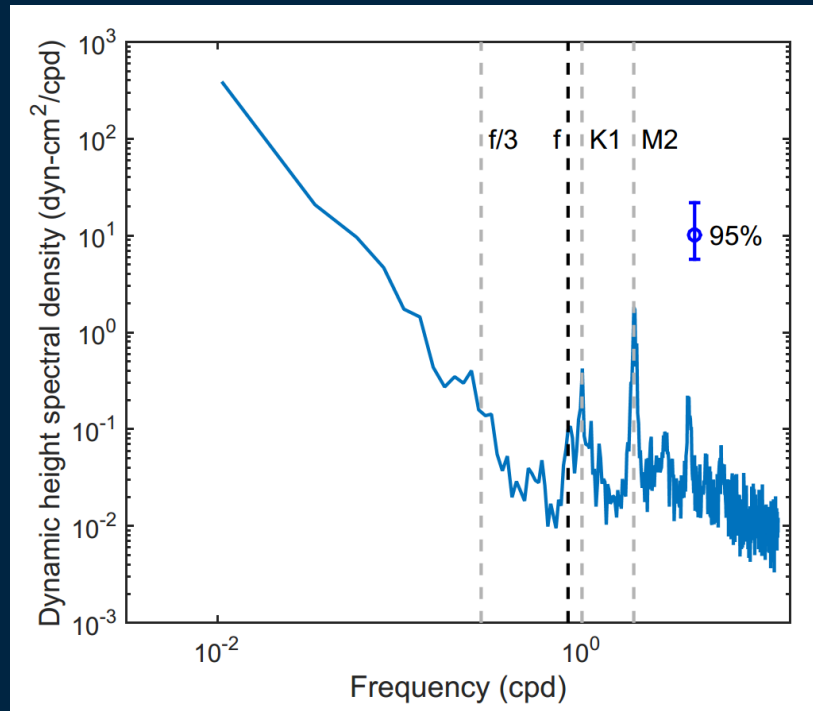# High-frequency variability vs SWOT noise floor

Salinity Processes Upper-ocean Regional Study (SPURS)

High-frequency variability vs SWOT noise floor

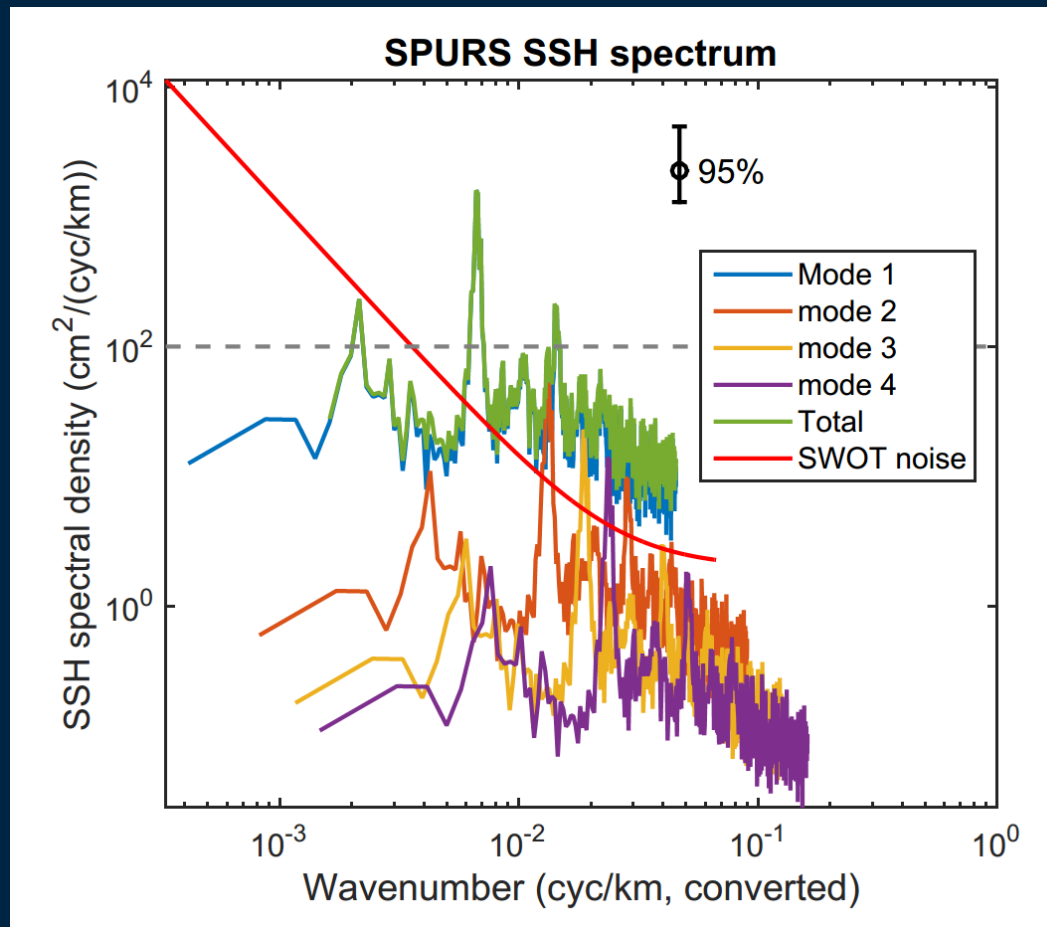Frequency spectrum of dynamic height relative to 400 m

For each vertical mode

$$\omega^2 = c^2\left(k_h{}^2\right) + f^2$$

High-frequency variability vs SWOT noise floor

Inferred internal-wave SSH wavenumber spectrum
(assumed lowest 4 modes contribute equally to dynamic height)

$$\omega^2 = c^2\left(k_h{}^2\right) + f^2$$

High-frequency variability vs SWOT noise floor

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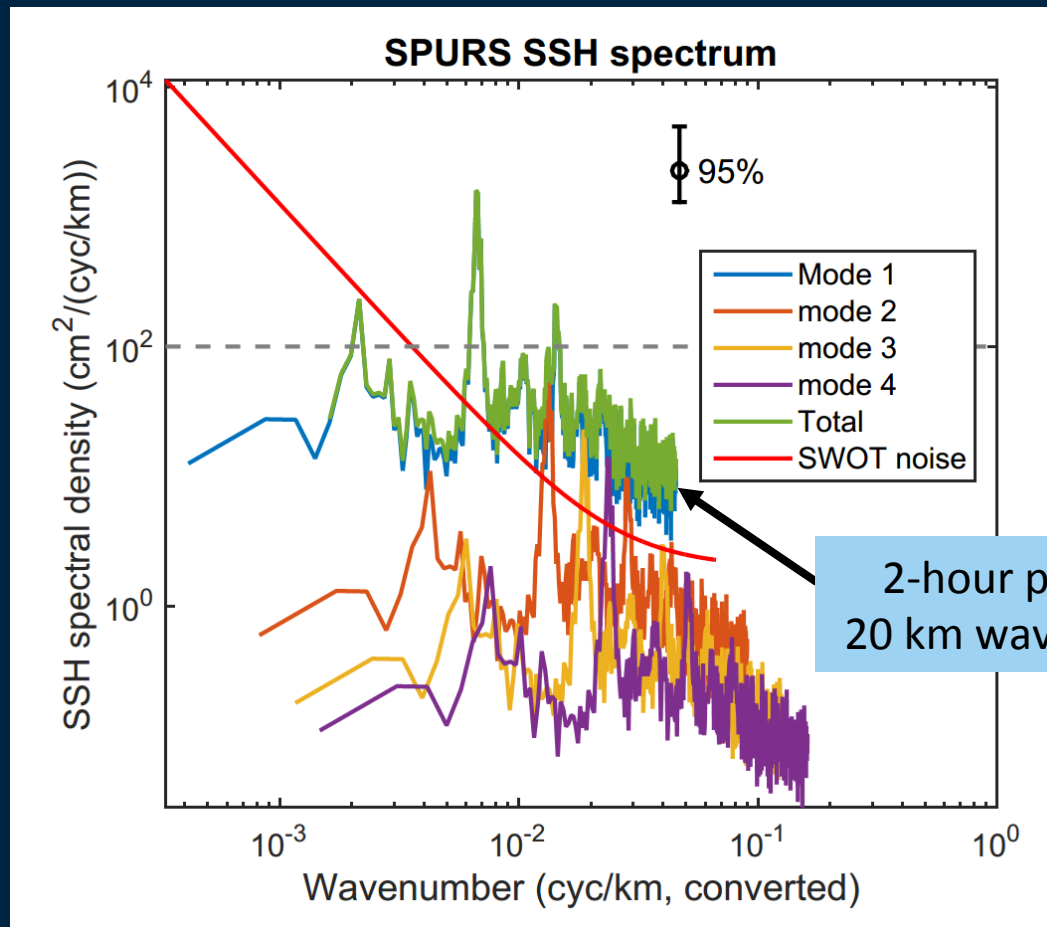(assumed lowest 4 modes contribute equally to dynamic height)

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